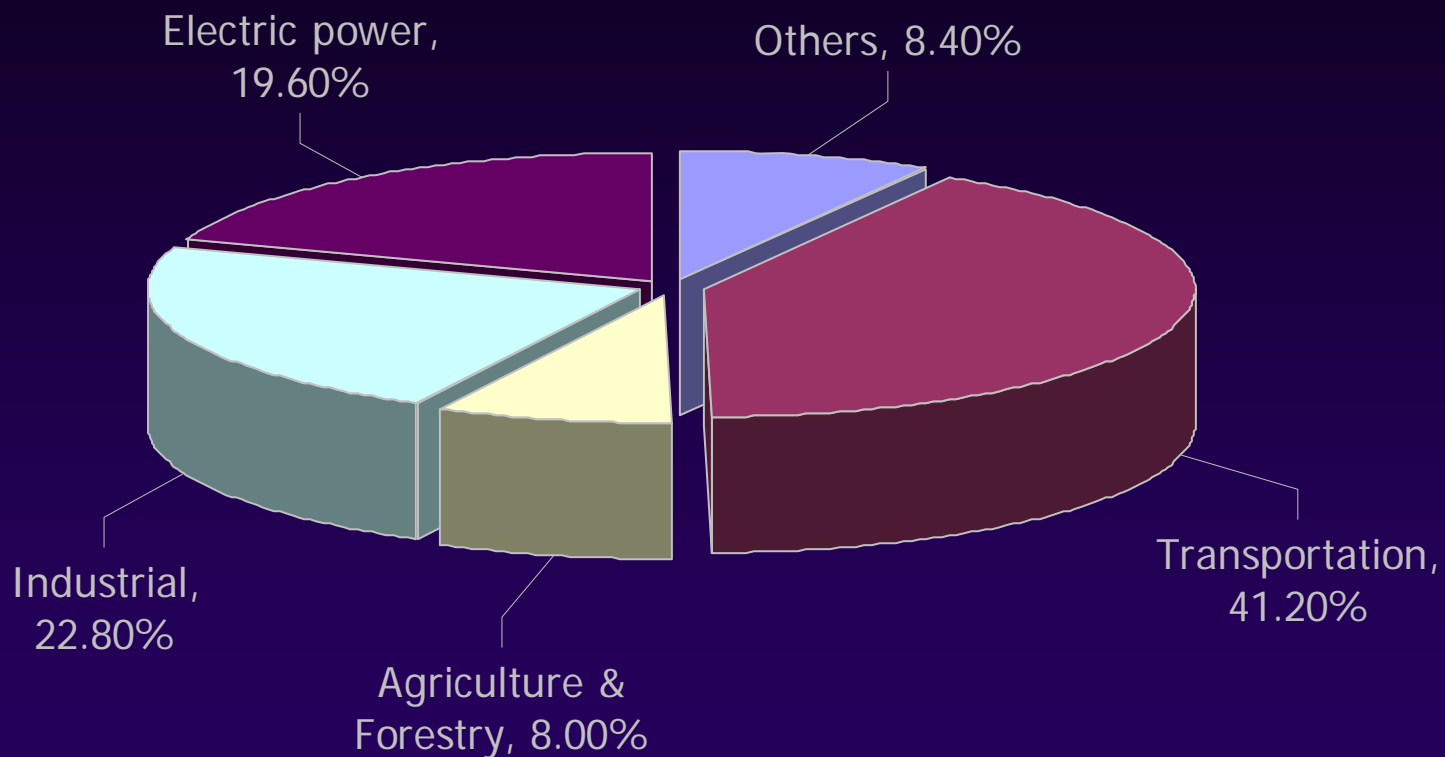


The Role of Agriculture in Mitigating Greenhouse Gas Emissions

Johan Six



Source of greenhouse gases in CA

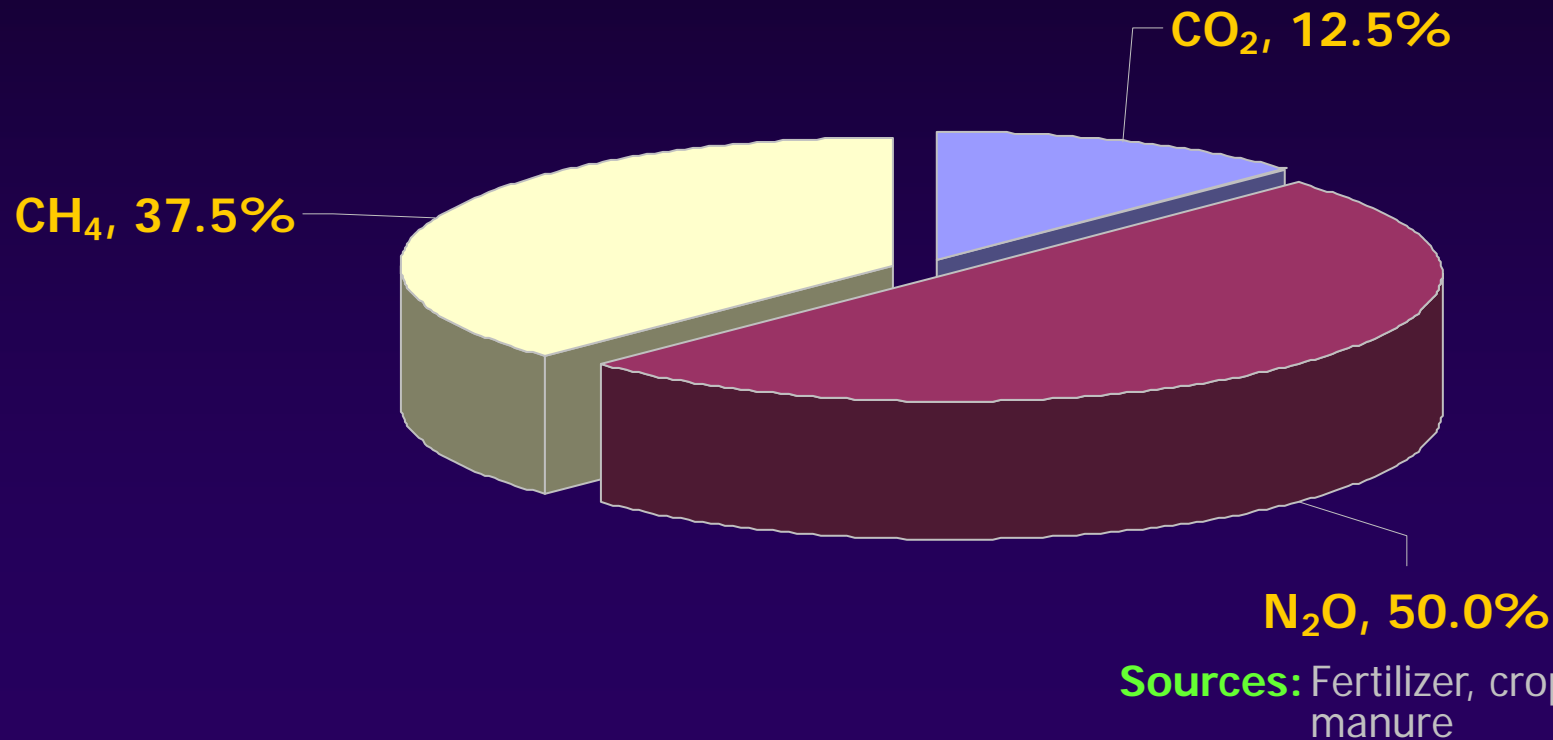


California Energy Commission, 2005

Composition and sources of greenhouse gases by agriculture

Sources: Livestock, manure, anaerobic soils (rice)

Sources: Fossil fuels, biomass burning, soil degradation



California Energy Commission, 2005

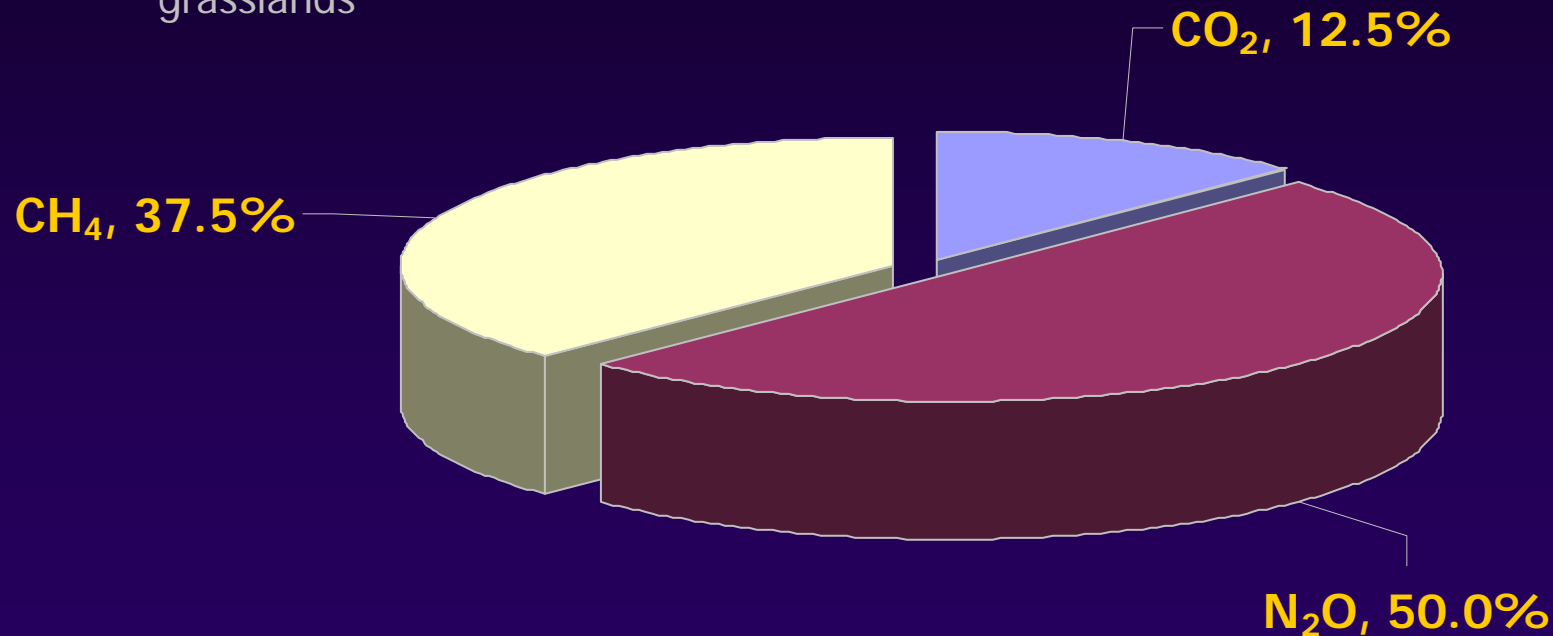
Composition and sinks of greenhouse gases by agriculture

Sources: Livestock, manure, anaerobic soils (rice)

Sinks: Aerobic soils, especially forests and grasslands

Sources: Fossil fuels, biomass burning, soil degradation

Sinks: Buildup soil organic matter and plant biomass



Sources: Fertilizer, crop residues, manure

Sinks: No sinks in soils

California Energy Commission, 2005

Practices for GHG mitigation

- Reduced or zero tillage
- Set-asides/conversions to perennial grass
- Winter cover crops
- More hay in crop rotations
- Higher residue (above- & below-ground) yielding crops
- Manure application and organic cropping
- Reducing fertilizer application rate

Research question:

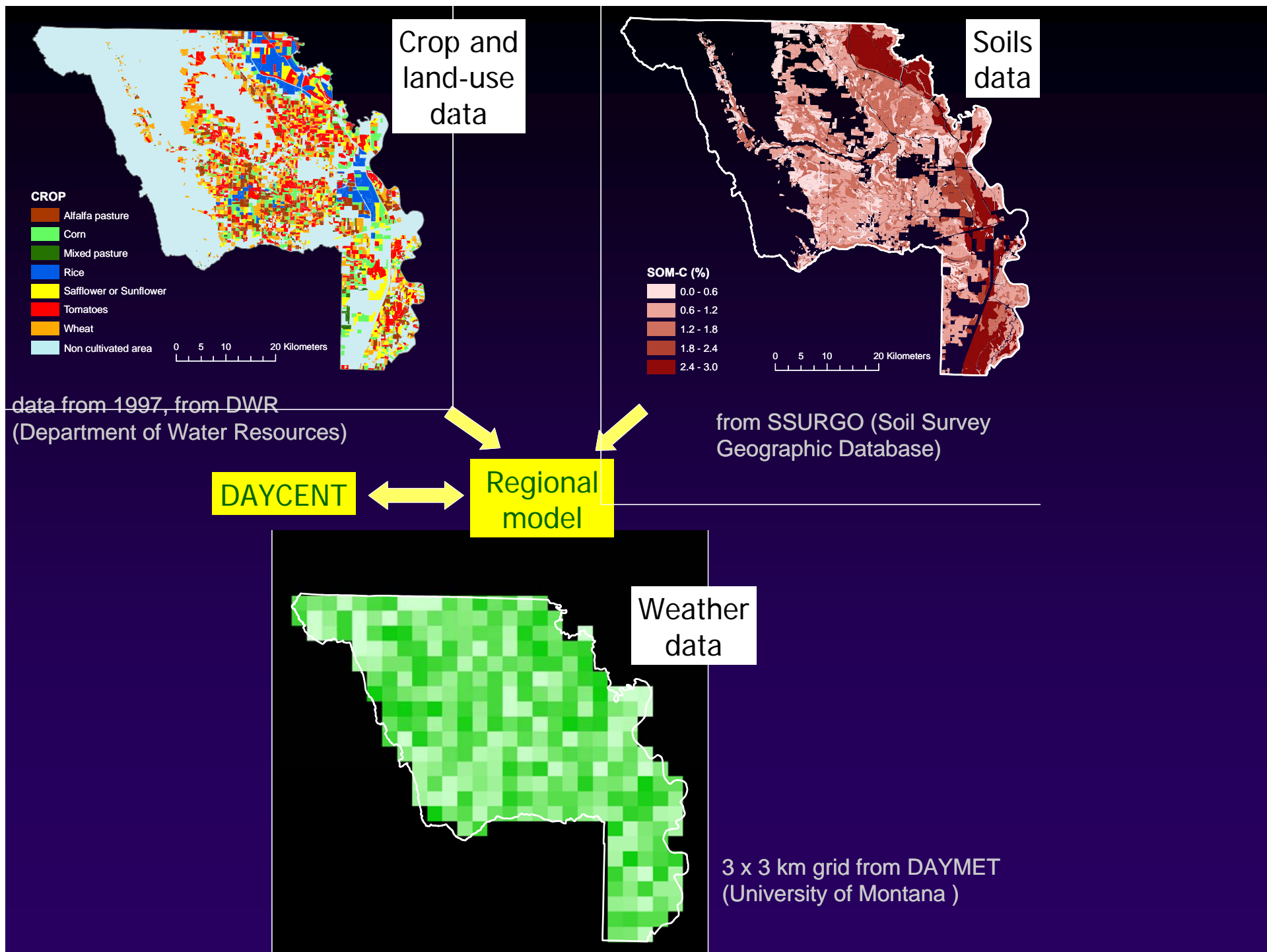


What is the **potential** for GHG mitigation by agriculture by changing practices for common crops and crop rotations in CA

= **emissions under alternative practices – emissions under conventional practices**

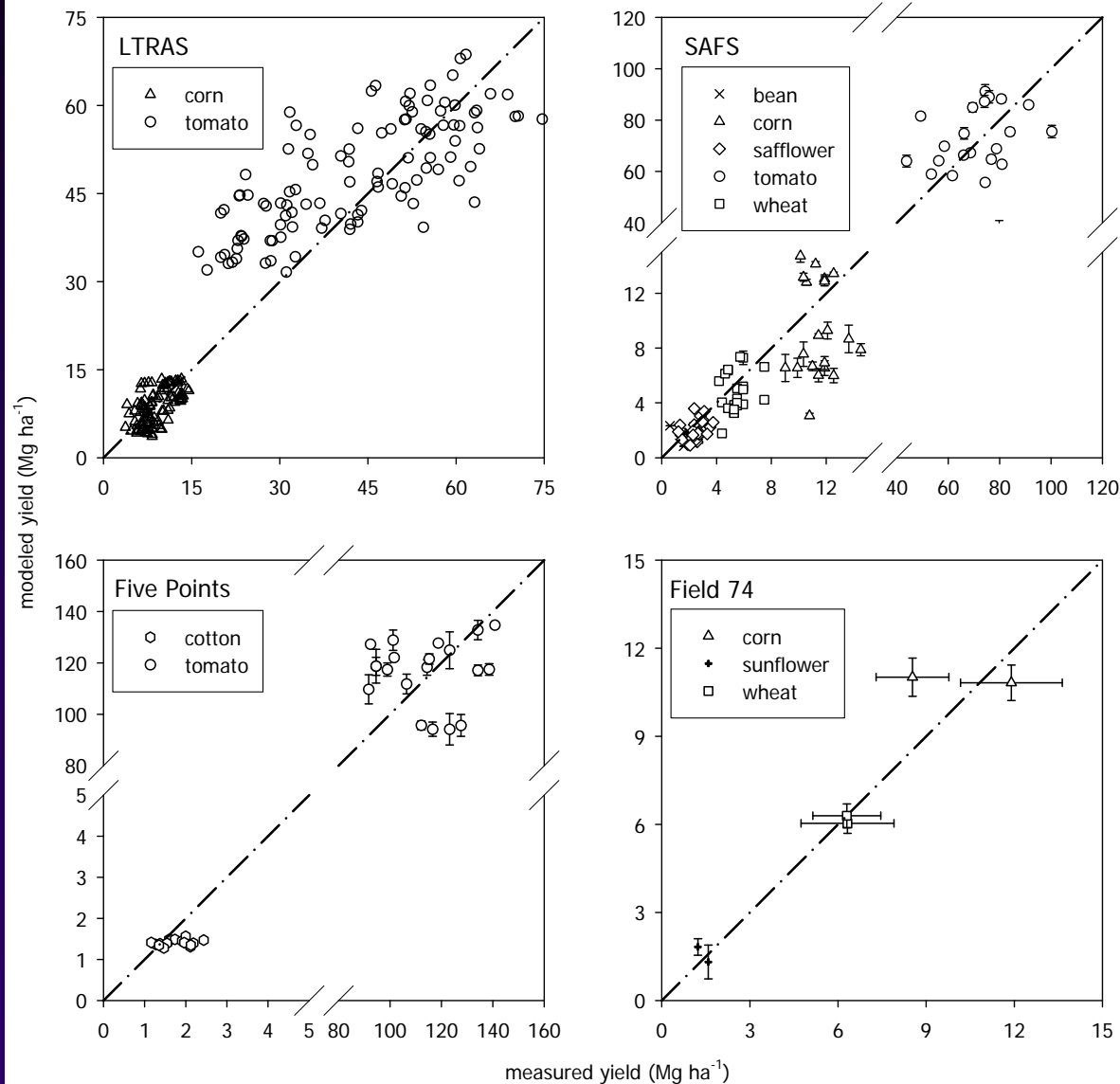
Assessing GHG emissions

- Integrating measurements with modeling
 - Measurements for calibration and validation of model
 - Modeling for regional extrapolation and prediction in a cost-effective way
 - Measurements to monitor and further validate model
- Integrating remote sensing
 - To assess temporal and spatial variability in crop growth and production



Validation: yields (Site)

Site level



Validation: yield and soil C (Site)

		LTRAS	SAFS	Five Points	Field 74
		prediction of yield			
variation explained by model (%)		86	92	94	92
partitioning of the MSD	non-unity slope (%)	13	4	3	5
	lack of correlation (%)	74	96	96	91
	square bias (%)	13	0	1	4
		prediction of soil organic carbon			
variation explained by model (%)		69	83	87	6
partitioning of the MSD	non-unity slope (%)	24	21	63	28
	lack of correlation (%)	70	56	31	45
	square bias (%)	6	23	6	27

Results (Site)

Site	Treatment or property	Δ SOC kg C ha ⁻¹ yr ⁻¹	N ₂ O kg N ha ⁻¹ yr ⁻¹	CH ₄ kg C ha ⁻¹ yr ⁻¹	GWP kg CO ₂ -eq ha ⁻¹ yr ⁻¹
LTRAS	Standard tillage	95 ± 46 ^c	3.18 ± 0.10	-1.52 ± 0.02	1081 ± 192
	Standard tillage and cover cropping	315 ± 46	2.60 ± 0.10	-1.44 ± 0.02	9 ± 192
	Standard tillage and organic	1324 ± 46	3.02 ± 0.10	-1.49 ± 0.02	-3496 ± 192
	<i>Proportion of variation due to seasonal differences^d</i>	74%	37%	46%	72%
	Conservation tillage	47 ± 87	3.01 ± 0.18	-1.51 ± 0.05	1182 ± 391
	Conservation tillage and cover cropping	321 ± 87	2.21 ± 0.18	-1.46 ± 0.05	-192 ± 391
	Conservation tillage and organic	1279 ± 87	2.98 ± 0.18	-1.49 ± 0.05	-3349 ± 391
	<i>Proportion of variation due to seasonal differences</i>	65%	53%	68%	61%

Results (Site)

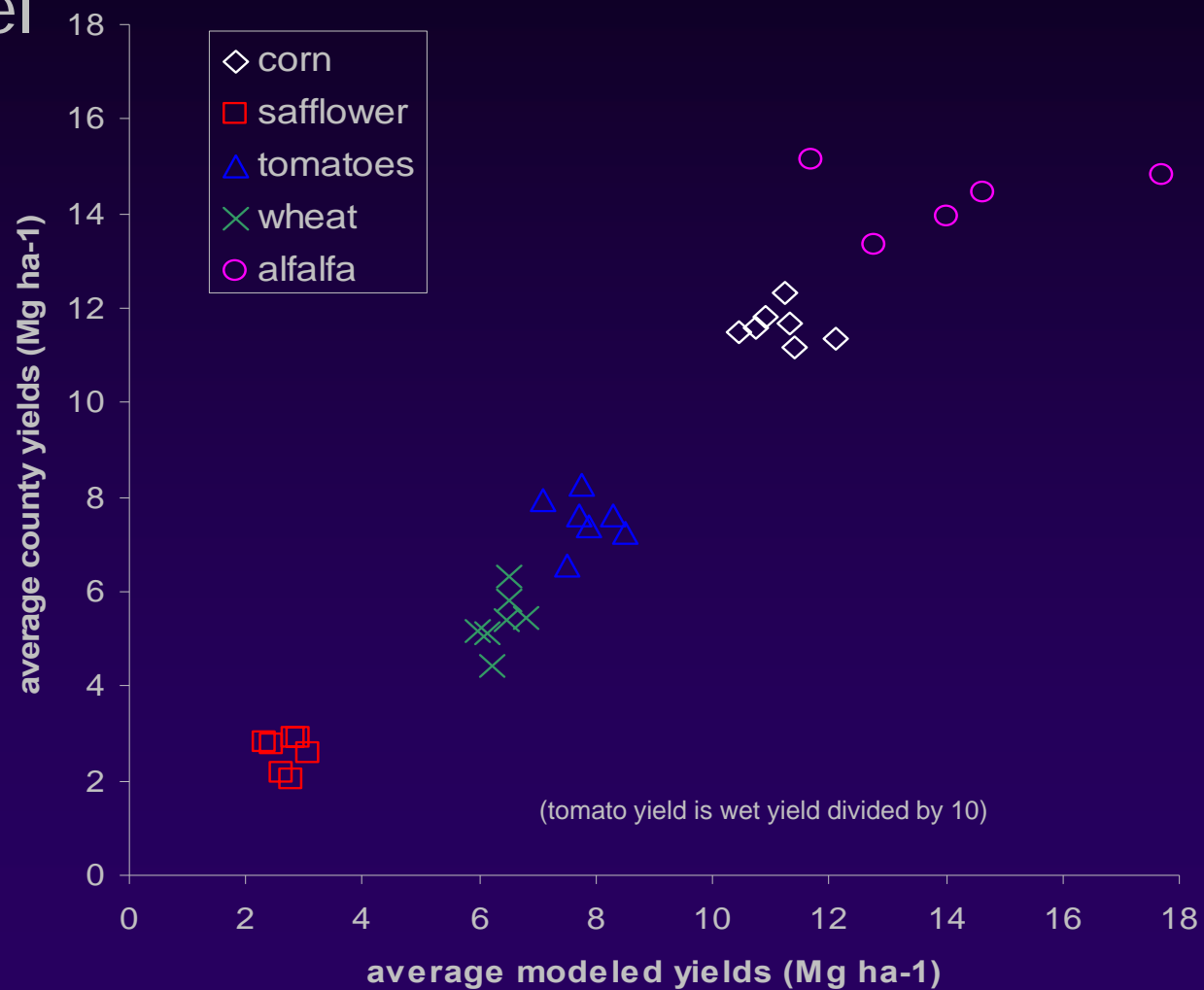
SAFS	Conventional 4-year rotation	407 ± 77	2.21 ± 0.08	-1.62 ± 0.02	-515 ± 292
	Conventional 2-year rotation	436 ± 78	1.54 ± 0.08	-1.44 ± 0.02	-925 ± 298
	Cover cropping	999 ± 77	1.70 ± 0.08	-1.63 ± 0.02	-2921 ± 292
	<i>Proportion of variation due to seasonal differences</i>	94%	80%	89%	96%
WSREC	Standard tillage	-90 ± 38	3.44 ± 0.10	-2.00 ± 0.02	1866 ± 147
	Standard tillage and cover cropping	677 ± 38	4.01 ± 0.10	-1.93 ± 0.02	-675 ± 147
	Conservation tillage	-9 ± 38	3.26 ± 0.10	-1.99 ± 0.02	1487 ± 147
	Conservation tillage and cover cropping	729 ± 38	3.79 ± 0.10	-1.94 ± 0.02	-969 ± 147
	<i>Proportion of variation due to seasonal differences</i>	91%	82%	38%	92%
Field 74	Standard tillage	128 ± 20	2.62 ± 0.08	-1.54 ± 0.04	700 ± 87
	Conservation tillage	256 ± 20	2.43 ± 0.08	-1.33 ± 0.04	150 ± 87
	<i>Proportion of variation due to seasonal differences</i>	51%	49%	19%	43%

Results (Site)

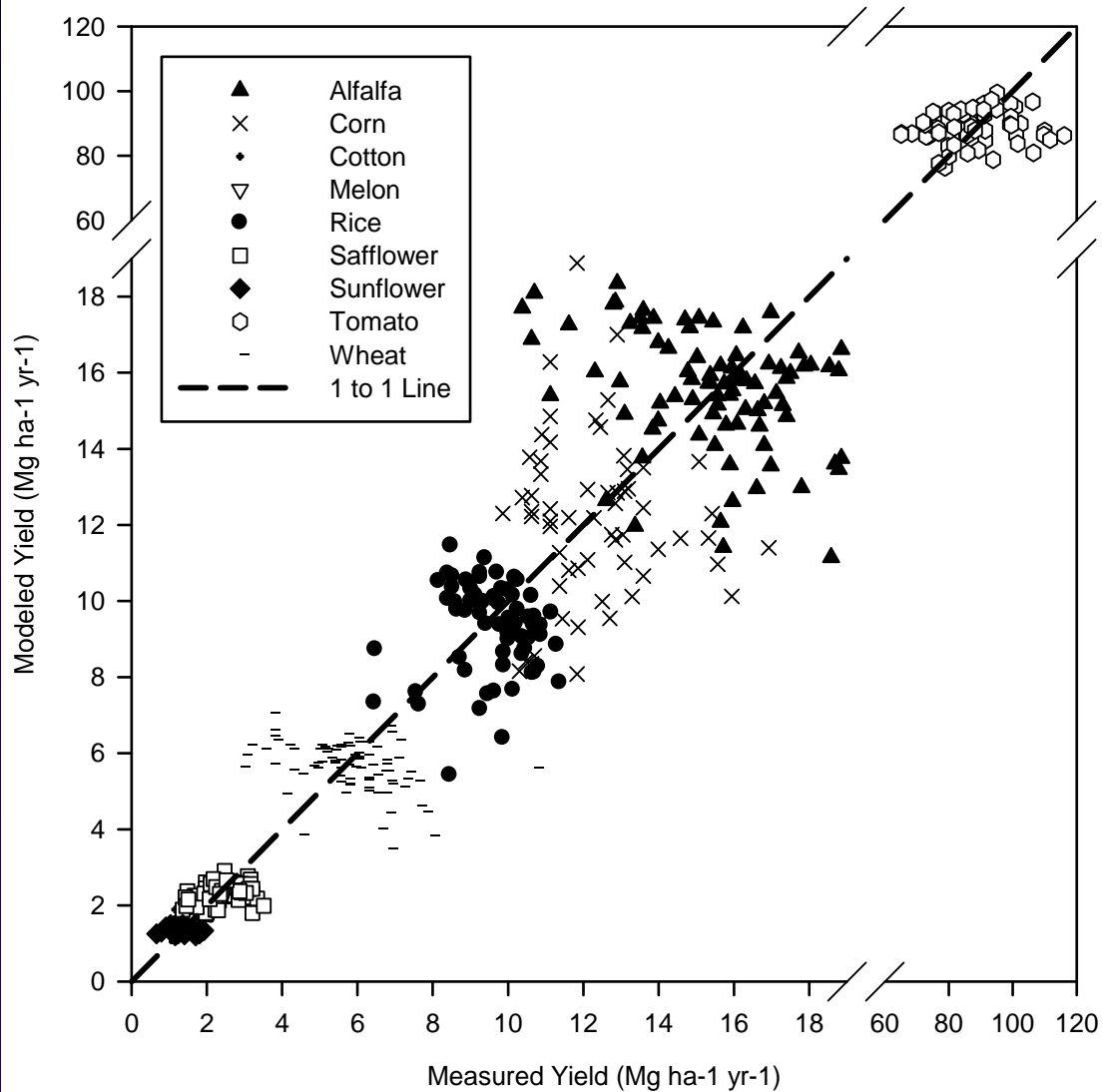
Site	Effect of treatment	ΔSOC^a kg C ha ⁻¹ yr ⁻¹	$\Delta\text{N}_2\text{O}^b$ kg N ha ⁻¹ yr ⁻¹	ΔCH_4^b kg C ha ⁻¹ yr ⁻¹	ΔGWP^b kg CO ₂ -eq ha ⁻¹ yr ⁻¹	Contribution of $\Delta\text{N}_2\text{O}$ to ΔGWP
LTRAS	Conservation tillage	36 ± 31	-0.07 ± 0.08	0.00 ± 0.01	-168 ± 131	20%
	Cover cropping ^c	220 ± 65	-0.58 ± 0.14	0.09 ± 0.03	-1072 ± 272	25%
	Manure application ^c	1229 ± 65	-0.16 ± 0.14	0.04 ± 0.03	-4577 ± 272	2%
SAFS	Cover cropping	577 ± 21	-0.18 ± 0.02	-0.10 ± 0.01	-2201 ± 82	4%
WSREC	Conservation tillage	66 ± 10	-0.20 ± 0.03	0.00 ± 0.01	-336 ± 47	28%
	Cover cropping	752 ± 10	0.55 ± 0.03	0.06 ± 0.01	-2499 ± 47	-10%
Field 74	Conservation tillage	128 ± 28	-0.19 ± 0.11	0.20 ± 0.05	-550 ± 123	16%

Validation: yields (Regional)

Regional level



Validation: yields (Regional)



Results (regional)

Tillage	Fertilizer	Cover crop	GWP		? SOC		N ₂ O	
			(Mg CO ₂ -eq ha ⁻¹ yr ⁻¹)		(kg C ha ⁻¹ yr ⁻¹)		(kg N ha ⁻¹ yr ⁻¹)	
Sacramento Valley								
convent.	mineral, 75%	no	-0.89	± 0.76	-2	± 16	-1.92	± 1.59
conserv.	mineral	no	-0.68	± 0.36	103	± 34	-0.64	± 0.56
convent.	mineral	yes	-1.36	± 0.89	310	± 180	-0.48	± 0.94
conserv.	mineral	yes	-1.37	± 0.88	312	± 178	-0.48	± 0.94
convent.	Organic	no	-1.16	± 0.78	158	± 63	-1.23	± 1.51
conserv.	Organic	no	-1.94	± 1.03	288	± 88	-1.89	± 1.86
convent.	Organic	yes	-2.60	± 1.87	405	± 212	-2.38	± 2.81
conserv.	Organic	yes	-3.29	± 2.07	532	± 246	-2.86	± 2.98
San Joaquin Valley								
convent.	mineral, 75%	no	-0.61	± 0.58	-4	± 14	-1.33	± 1.24
conserv.	mineral	no	-0.57	± 0.33	81	± 35	-0.59	± 0.55
convent.	mineral	yes	-1.35	± 1.07	284	± 170	-0.66	± 1.36
conserv.	mineral	yes	-1.38	± 1.08	287	± 169	-0.68	± 1.39
convent.	Organic	no	-0.49	± 0.89	154	± 54	0.16	± 1.96
conserv.	Organic	no	-1.14	± 0.90	255	± 79	-0.43	± 1.82
convent.	Organic	yes	-1.87	± 1.41	395	± 203	-0.89	± 2.41
conserv.	Organic	yes	-2.45	± 1.52	498	± 235	-1.32	± 2.41

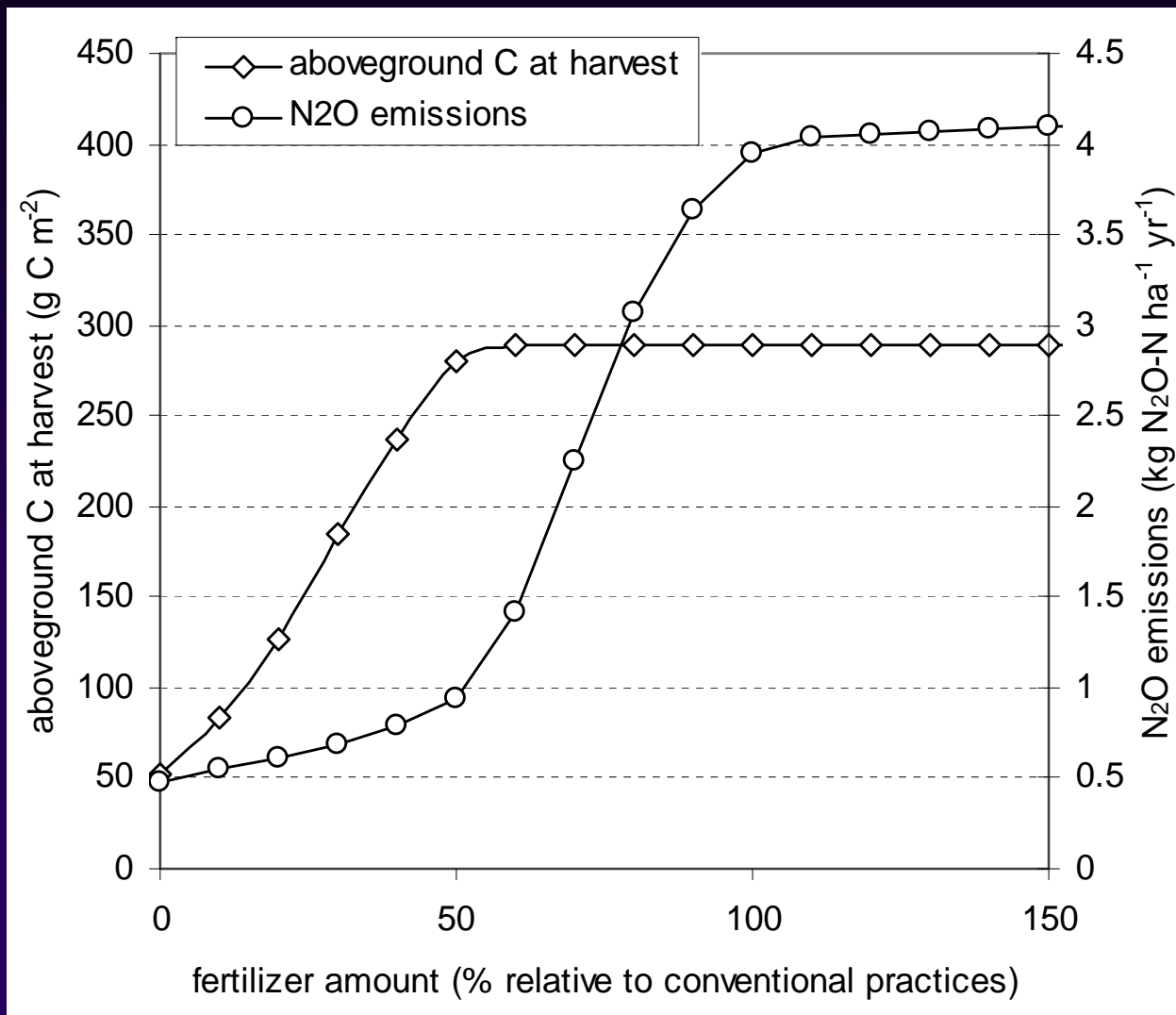
3 concerns around C-sequestration

- **Permanence**
 - They have to be secured over the long run
- **Additionality**
 - Carbon stocks with project activities compared to carbon stocks without project activities
- **Leakage**
 - Potential negative C flows due to the project (on land outside of the project) must be addressed
 - Migration of people who were farming on the land to other places and clearing forest somewhere else

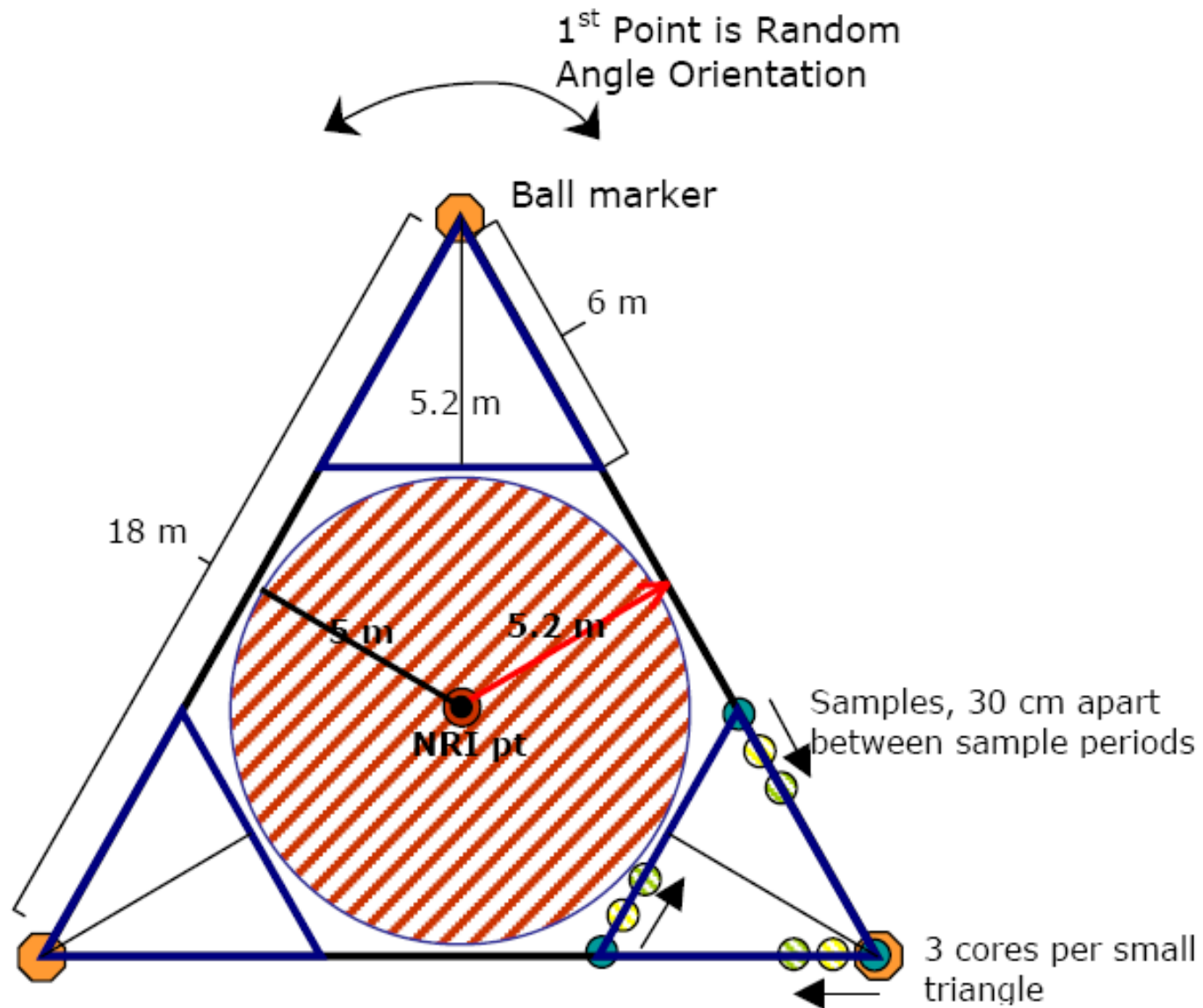
Future needs

- Get a handle on nitrous oxide
- Monitoring
- Decision support tool for stakeholders
 - COMET-VR

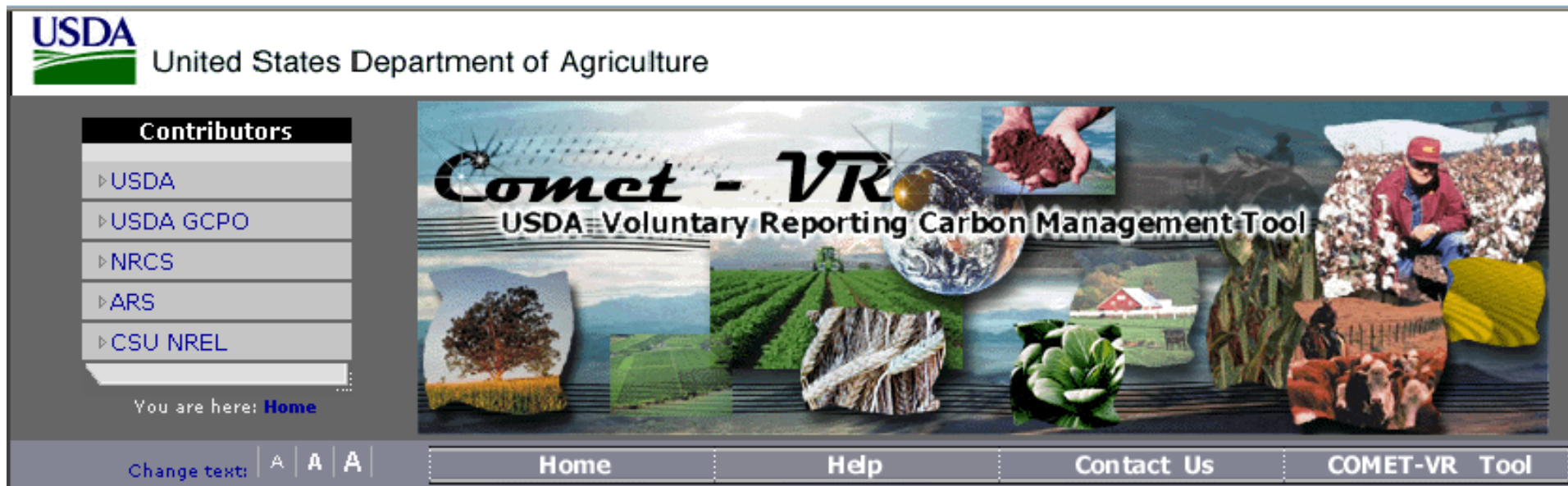
N₂O ~ crop growth



Monitoring



COMET-VR (CarbOn Management and Evaluation Tool – Voluntary Reporting)



- Currently supports soil C change estimates and fuel usage
- N₂O emissions will be incorporated in the next version
- Perennial systems need to be optimized

THANKS!

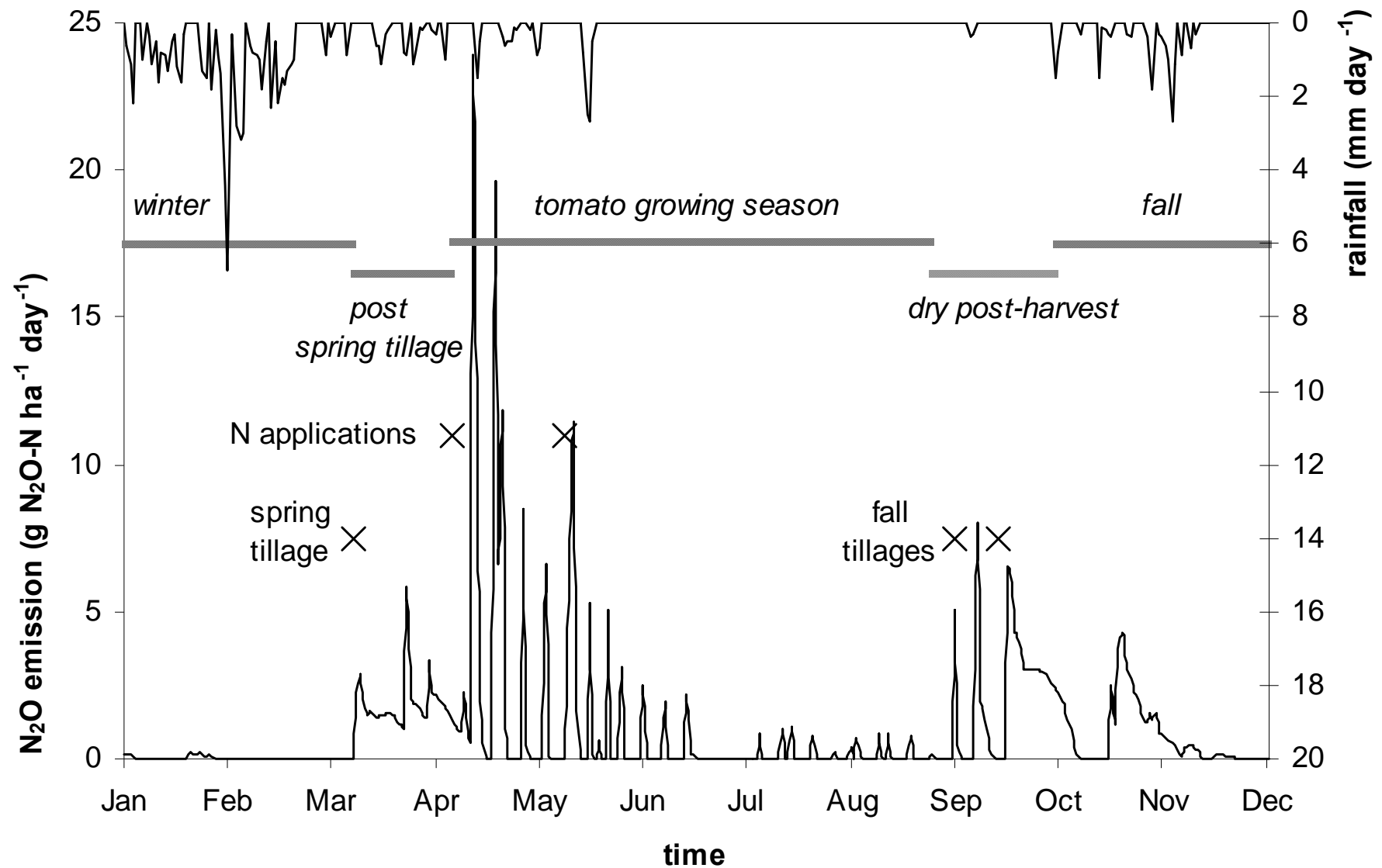
De Gryze et al. 2009. Modeling shows that alternative soil management can decrease greenhouse gases. Cal. Ag. 63:84-90.

Howitt et al. 2009. Realistic payments could encourage farmers to adopt practices that sequester carbon. Cal. Ag. 63:91-95.

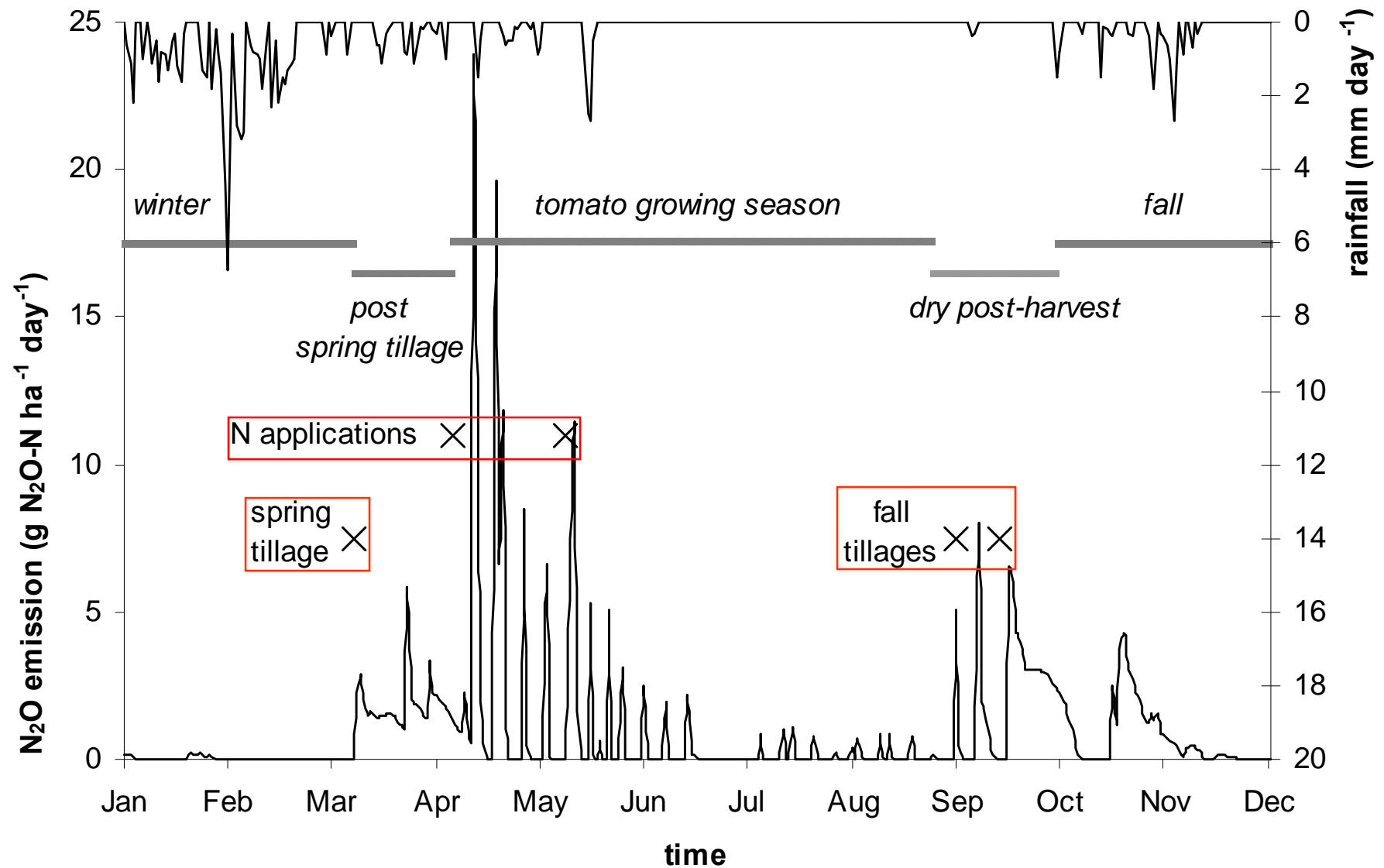
<http://calag.ucop.edu/0902AMJ/toc.html>



N₂O: variability!



N₂O: targeted measures



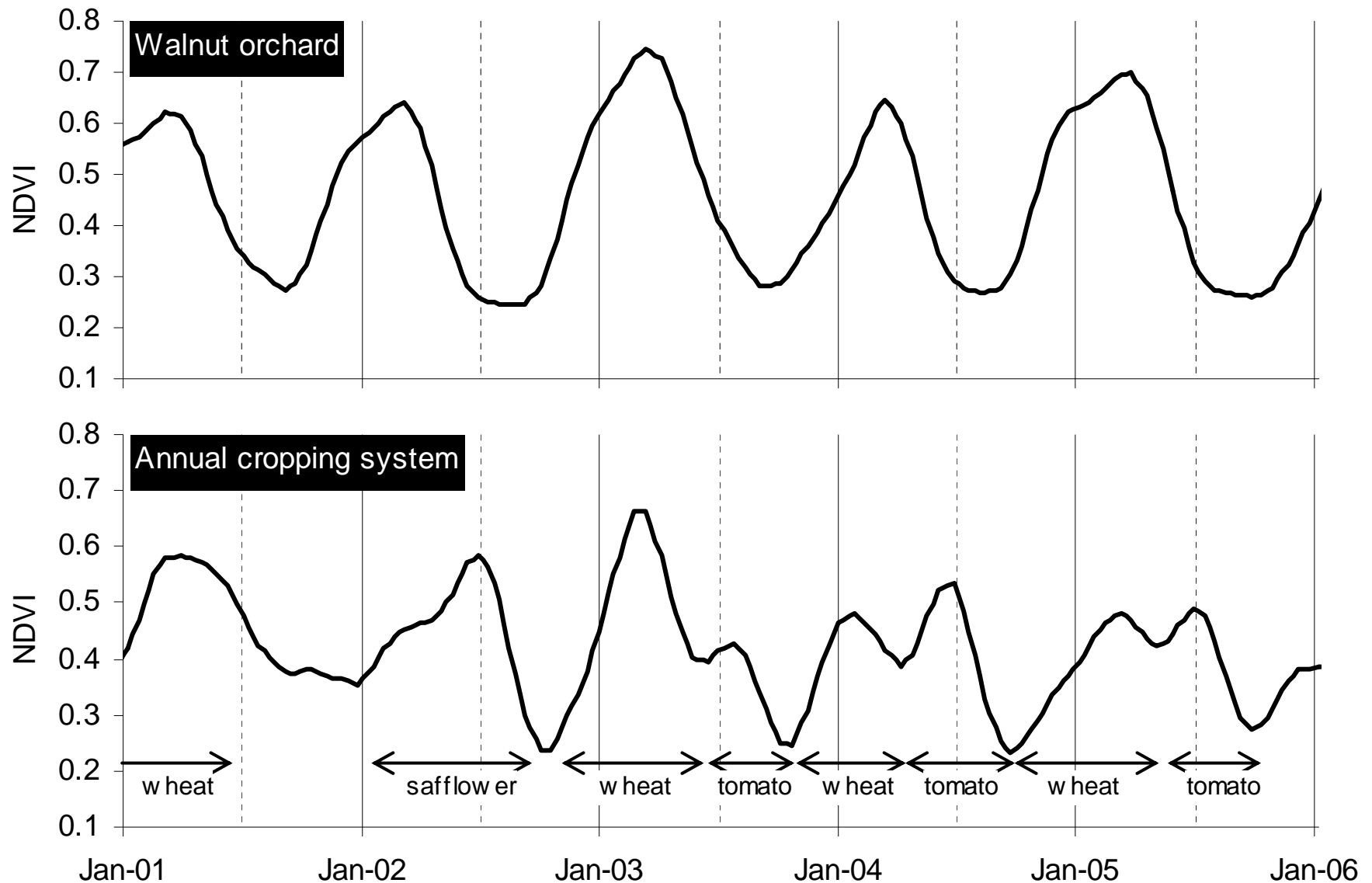
Perennial crops!

area rank	crop	area (1000 acres)	economical value (\$million)	economical rank
1	hay (mainly alfalfa)	1550	1141	6
2	nuts (almonds, walnuts and pistachios)	900	3454	1
3	grapes	800	3166	2
4	cotton	657	625	11
5	rice	526	408	13
6	intensely cropped vegetables (lettuce, broccoli, carrots, celery and peppers)	496	2920	3
7	wheat	369	104	>15
8	fruit trees (oranges, plums, lemon, peaches)	359	1292	5
9	tomatoes	307	942	9
10	corn	110	52	>15

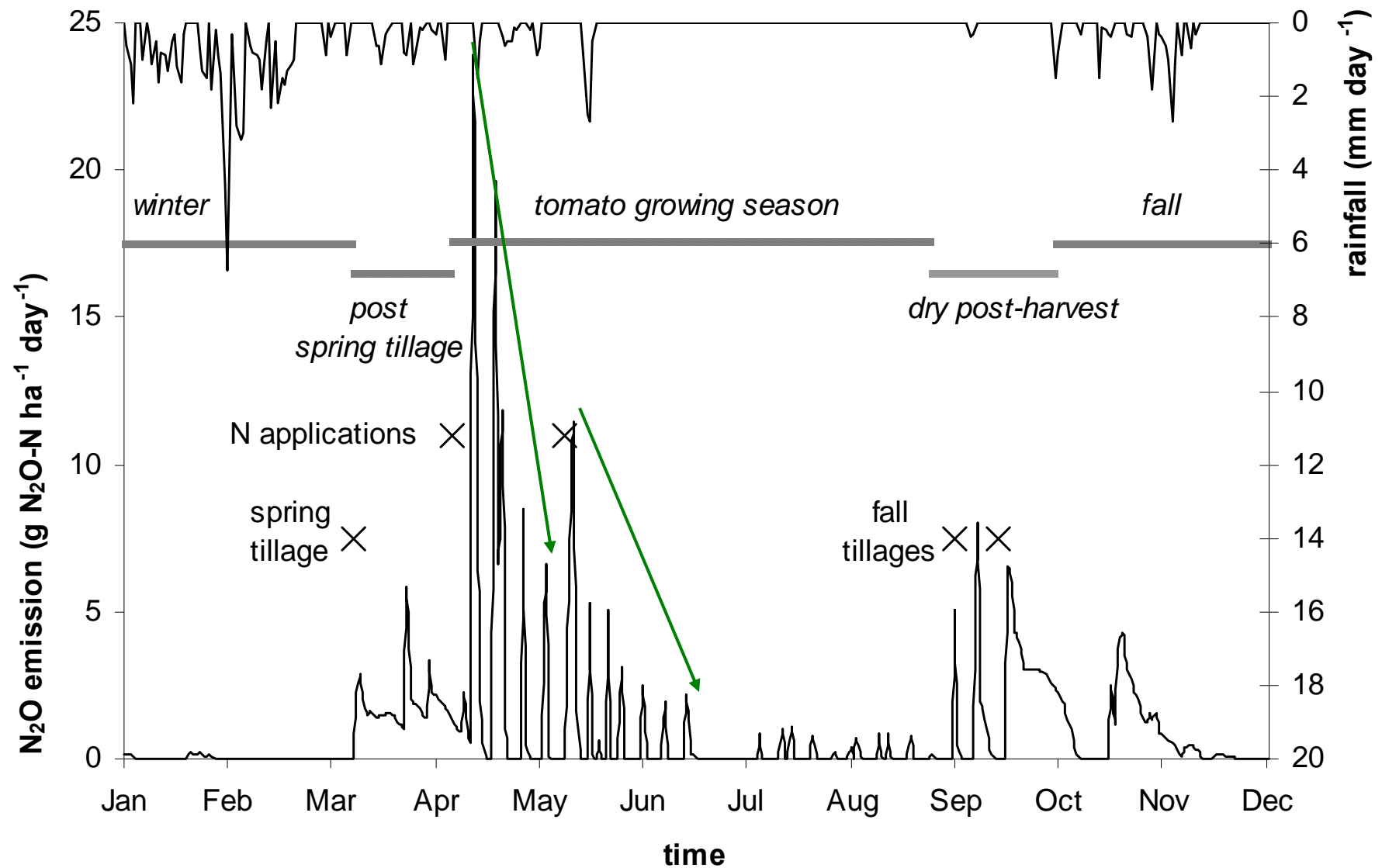
N₂O?

cropping system	nr observations in literature
alfalfa	4
nut orchards	0
vineyards	0
cotton	5
rice	78
intensely cropped vegetables	29
wheat	77
fruit orchards	0
tomato	6
corn	157

Remote sensing of crop growth



N₂O: variability!



Online Tool for Agriculture & Range

[Go to](#) | [Reset](#) | [State](#) |

COMET-VR is the first Online Carbon Estimator Tool from Natural Resources Conservation Service (NRCS) and Natural Resource Ecology Laboratory, (NREL), Colorado State University, (CSU), developed in response to global climate change. This tool estimates carbon that is sequestered in the soil based on land management in agriculture. COMET-VR gives you an idea of the magnitude of agricultural management practices on carbon sequestration. The management practices covered are limited to the most predominant in the MLRA. NRCS specialists and the NRCS NRI were used to identify each practice.

Step 1. Enter the State Information: Select the State where the parcel is located from the list of State Names.

State Selection:

Select a State: Indiana ?

Next

USDA COMET-VR Online Tool 012007

Selection

Session Information: ?

- ID: 1
- ID: 2 122271884
- ID: 3 122272107

Enter Session ID: Go

Location Information:

Parcel Information:

Select state and county

Online Tool for Agriculture & Range

[Go to](#) | [Reset](#) | [State](#) | [County](#) |

Step 2. Enter the County Information: Select the County where the parcel is located from the list of County Names.

Indiana County Selection:

Select a County: GIBSON ?

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Next

USDA COMET-VR Online Tool 2007

Selection

Session Information: ?

- ID: 1
- ID: 2 122271884
- ID: 3 122272107

Enter Session ID: Go

Location Information:

- State: Indiana

Parcel Information:

Online Tool for Agriculture & Range

[Go to](#) | [Reset](#) | [State](#) | [County](#) | [Parcel](#) | [Soil](#) | [Rotation](#) | [Tillage](#) | [Submit](#) | [Summary](#) | [Fuel](#) | [File](#) |

Step 4. Enter the Soil Information: Select the dominant soil texture and hydric information for your parcel.

GIBSON County, Indiana Soil Selection:

Select the surface soil texture:

sandy clay loam
sandy loam
silt
silt loam
silty clay
silty clay loam

Is this a hydric soil?
Select No or Yes:

☐ No ☐ Yes ?

Back

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Selection

Session Information: ?

- ID: 1
- ID: 2 122271884
- ID: 3 122272107

Enter Session ID: Go

Location Information:

- State: Indiana
- County: GIBSON
- Fips: 18051
- MLRA: 115A
- LRR: M

Parcel Information:

- Report Date: 2/1/2007
- Name: North Forty
- Size: 40 Acres
- Type: Agriculture

Soil Information:

- Texture: silty clay loam
- Hydric: N

Select soil type and drainage condition

[Go to](#) | [Reset](#) | [State](#) | [County](#) | [Parcel](#) | [Soil](#) | [Rotation](#) |

Step 5. Enter the land management information: Choose a rotation for the four time periods. ?

The following cropping systems were identified as having the greatest harvested crop acreage in your county using production data from the National Agricultural Statistics Service and the NRCS Natural Resource Inventory. They may not be the most common cropping systems in your immediate neighborhood but are the most significant cropping systems in your county.

Please select the system that most closely resembles your land management practice. Choose a rotation that is most like your land management that produces a similar residue, and fertilizer application. Or select **Other**. Other represents the most dominate cropping system for your county according to current data.

GIBSON County, Indiana Management History for North Forty:

Choose A Rotation for each Management Time Period:

All Rotations

1. Landscape position and historical management:

<input type="radio"/> Livestock Grazing (pre 1970s)
<input type="radio"/> Lowland Non-Irrigated (pre 1970s)
<input type="radio"/> Upland Non-Irrigated (pre 1970s)

Sort By: ☐ Non-Irrigated ☐ Irrigated ☐ Grazing ☐ AgroForestry ☒ All
Number of Records: 3

All Rotations

2. 1970s through mid-1990s:

<input type="radio"/> Livestock Grazing: seasonal, heavy grazing, low fertilizer
<input type="radio"/> Livestock Grazing: year round, heavy grazing, low fertilizer
<input type="radio"/> Non-Irrigated: corn-soybean
<input type="radio"/> Non-Irrigated: corn-soybean-winter wheat
<input type="radio"/> Other

Sort By: ☐ Non-Irrigated ☐ Irrigated ☐ Grazing ☐ AgroForestry ☐ OTHER ☒ ALL
Number of Records: 5

Conservation Reserve Program (CRP) Enrollment during 1980s?

Select the CRP type:

<input type="radio"/> 100% grass
<input type="radio"/> grass/legume mixture
<input type="radio"/> None

All Rotations

3. Base (Current Management):

<input type="radio"/> Non-Irrigated: corn-oats-5 yrs grass/legume pasture
<input type="radio"/> Non-Irrigated: corn-sorghum
<input type="radio"/> Non-Irrigated: corn-soybean
<input type="radio"/> Non-Irrigated: corn-soybean-5 yrs legume hay
<input type="radio"/> Non-Irrigated: corn-soybean-winter wheat
<input type="radio"/> Non-Irrigated: corn-winter wheat

Sort ☐ Non-Irrigated ☐ Irrigated ☐ Grazing ☐ AgroForestry ☐ CRP ☐ OTHER
By: ☒ ALL
Number of Records: 35

All Rotations

4. 2007 Report Period:

<input type="radio"/> Non-Irrigated: corn-oats-5 yrs grass/legume pasture
<input type="radio"/> Non-Irrigated: corn-sorghum
<input type="radio"/> Non-Irrigated: corn-soybean
<input type="radio"/> Non-Irrigated: corn-soybean-5 yrs legume hay
<input type="radio"/> Non-Irrigated: corn-soybean-winter wheat
<input type="radio"/> Non-Irrigated: corn-winter wheat

Sort ☐ Non-Irrigated ☐ Irrigated ☐ Grazing ☐ AgroForestry ☐ CRP ☐ OTHER
By: ☒ ALL
Number of Records: 35

[Back](#)

[Reset](#)

[Next](#)

Selection

Session Information: ?

- ☐ ID: 1
- ☐ ID: 2 122271884
- ☐ ID: 3 122272107

Enter Session ID: [Go](#)

Location Information:

- ☐ State: Indiana
- ☐ County: GIBSON
- ☐ Fips: 18051
- ☐ MLRA: 115A
- ☐ LRR: M

Parcel Information:

- ☐ Report Date: 2/1/2007
- ☐ Name: North Forty
- ☐ Size: 40 Acres
- ☐ Type: Agriculture

Soil Information:

- ☐ Texture: silty clay loam
- ☐ Hydric: N

Management History:

See Also

- ☐ NRCS Energy Estimator for Tillage
- ☐ NREL Agroecosystems
- ☐ CASMGS Consortium for Agricultural Soils Mitigation of Greenhouse Gases
- ☐ ARS Research
- ☐ U.S. Agriculture & Forestry Greenhouse Gas Inventory
- ☐ Greenhouse Gas Reporting Guidelines
- ☐ Greenhouse Gas Guidance for FARMS and FORESTS
- ☐ Draft 1605b Technical Guidelines
- ☐ 1605b Voluntary Reporting Program
- ☐ COLE Forestry Model
- ☐ COLE Lite Forestry Model

Select management sequences

Select tillage management sequence

Online Tool for Agriculture & Range

[Go to](#) | [Reset](#) | [State](#) | [County](#) | [Parcel](#) | [Soil](#) | [Rotation](#) | [Tillage](#) |

Step 6. Enter the land management information: Choose a tillage for the three time periods.

GIBSON County, Indiana Tillage History for North Forty

Enter the management history for this parcel: ?

Tillage For this Time Period: Choose Tillage:

1970s through mid-1990s:	<input type="radio"/> Intensive Tillage
	<input type="radio"/> Reduced Tillage
	<input type="radio"/> No Till Tillage
Base (Current Mgmt.):	<input type="radio"/> Intensive Tillage
	<input type="radio"/> Reduced Tillage
	<input type="radio"/> No Till Tillage
2007 Report Period:	<input type="radio"/> Intensive Tillage
	<input type="radio"/> Reduced Tillage
	<input type="radio"/> No Till Tillage

[Back](#)

[Reset](#)

[Next](#)

Selection

Session Information: ?

- ☐ ID: 1
- ☐ ID: 2 122271884
- ☐ ID: 3 122272107

Enter Session ID: [Go](#)

Location Information:

- ☐ State: Indiana
- ☐ County: GIBSON
- ☐ Fips: 18051
- ☐ MLRA: 115A
- ☐ LRR: M

Parcel Information:

- ☐ Report Date: 2/1/2007
- ☐ Name: North Forty
- ☐ Size: 40 Acres
- ☐ Type: Agriculture

Soil Information:

- ☐ Texture: silty clay loam
- ☐ Hydric: N

Voluntary Reporting

Carbon Management Tool COMET-VR

Carbon Storage Report ?

Report Year: 2007

ID: 589453228

Parcel Description

Parcel Type:	Agriculture
Total Parcels for this Entity:	1
Parcel Name:	Parcel 1
Parcel Size:	100 Hectares
Location:	GIBSON, Indiana
Soil:	Non-hydric silty clay loam

Parcel Management History

Historic:	Upland Non-Irrigated (pre 1970s)
70s to 90s:	Non-Irrigated: corn-soybean; Intensive Tillage
Current:	Non-Irrigated: corn-soybean; Intensive Tillage
Report Period:	Non-Irrigated: corn-soybean; No Till Tillage

Predicted Change in Soil Carbon for the Parcel

Annual Change for 2007

	Carbon Change	Uncertainty ?		
		Avg Percent	Lower Bounds CI*	Upper Bounds CI*
Total Tonnes Carbon per year:	39.39	0.00 %	13.67	20.08
Total Tonnes CO2 Equivalent per year:	144.32	0.00 %	22.33	50.07

Values recorded in Metric units. One **tonne** of carbon is equivalent to 3.664 **tonnes** of carbon dioxide.

Please report the **Large Bolded Values** on your 1605B report for carbon change and uncertainty. We are 95% confident that your actual carbon change value is within (+/-) 100 % of the modeled carbon change value shown on this report.

Location Information:

- **State:** Indiana
- **County:** GIBSON
- **Fips:** 18051
- **MLRA:** 115A
- **LRR:** M

Parcel Information:

- **Report Date:** 2/15/2007
- **Name:** Parcel 1
- **Size:** 100 Hectares
- **Type:** Agriculture

Soil Information:

- **Texture:** silty clay loam
- **Hydric:** N

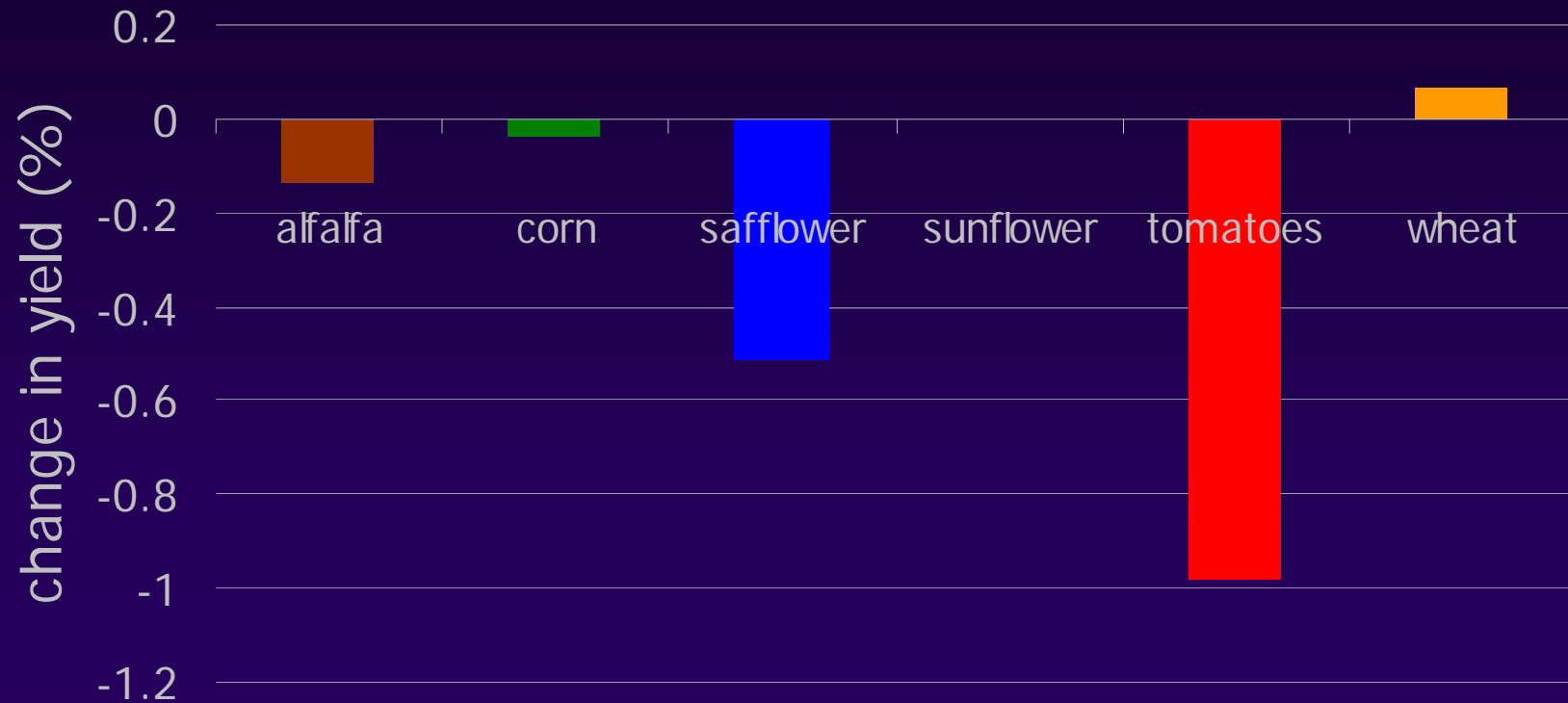
Management History:

- **Historic:** Upland Non-Irrigated (pre 1970s)
- **70's - 90's:** Non-Irrigated: corn-soybean, Intensive Tillage, CRP: None
- **Current:** Non-Irrigated: corn-soybean, Intensive Tillage,
- **Report Period:** Non-Irrigated: corn-soybean, No Till Tillage,

See Also

- **NRCS Energy Estimator for Tillage**
- **NREL Agroecosystems**
- **CASMGS Consortium for Agricultural Soils Mitigation of Greenhouse Gases**
- **ARS Research**
- **U.S. Agriculture & Forestry Greenhouse Gas Inventory**
- **Greenhouse Gas Reporting Guidelines**
- **Greenhouse Gas Guidance for FARMS and FORESTS**
- **Draft 1605b Technical Guidelines**
- **1605b Voluntary Reporting Program**

Results: conventional to reduced tillage – change in yield



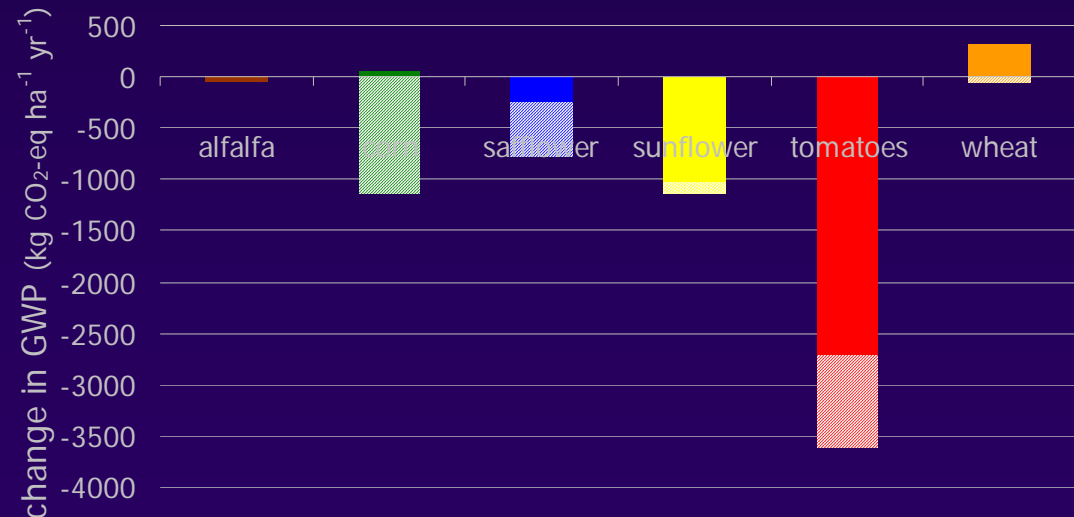
Results: conventional to reduced tillage – GHG difference

total change:

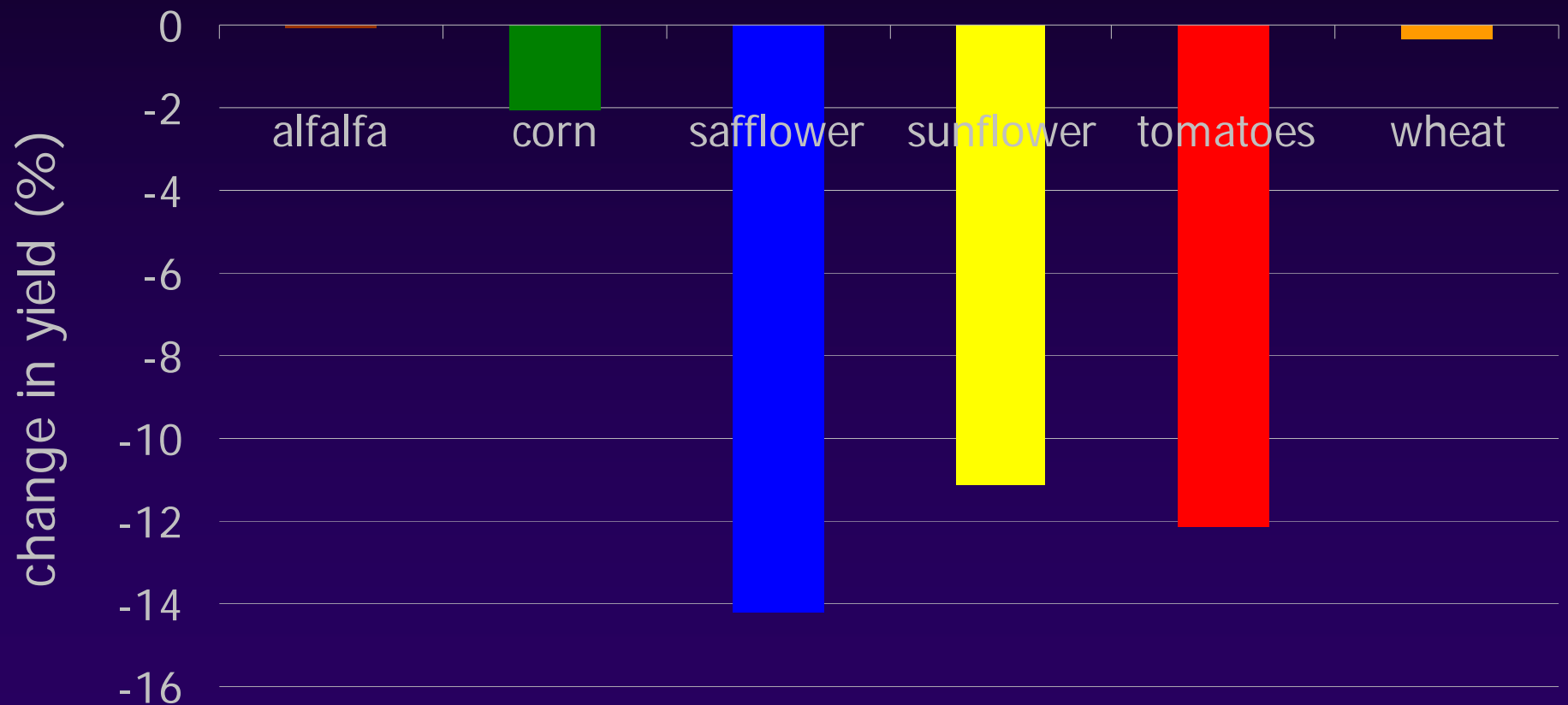


contribution of separate gases:

■ contribution of CO₂
▨ contribution of N₂O



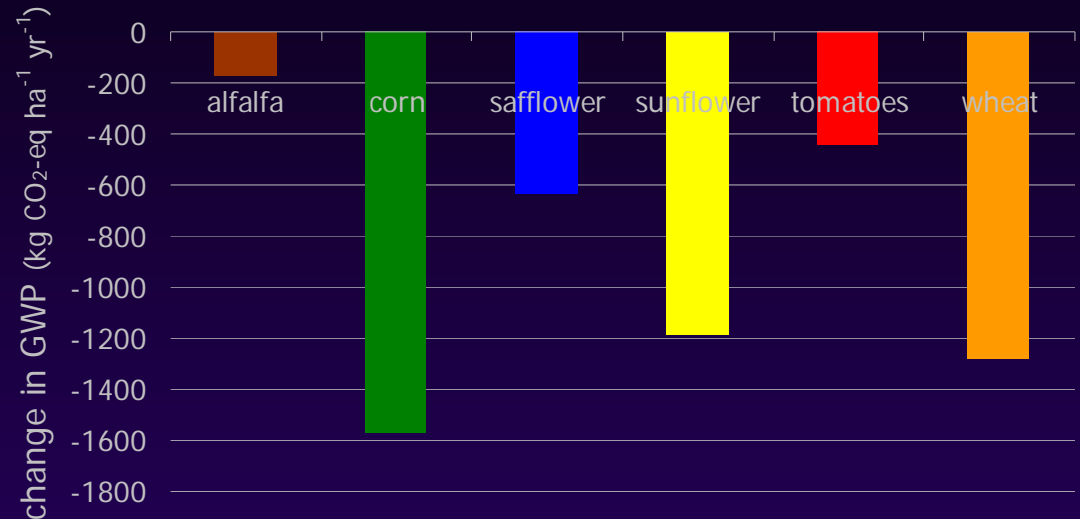
Results: conventional to low input – change in yield



Results: conventional to low input

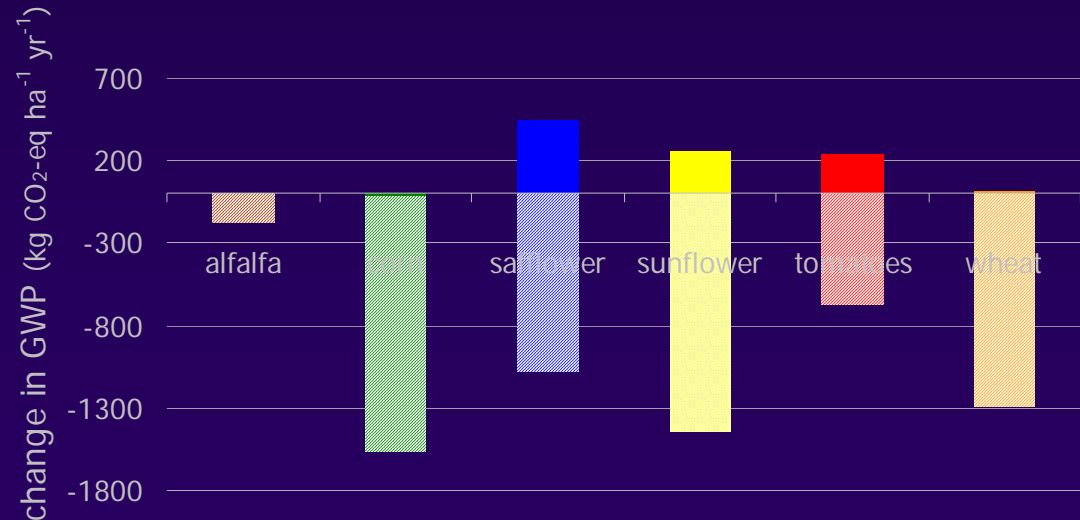
– GHG difference

total change:



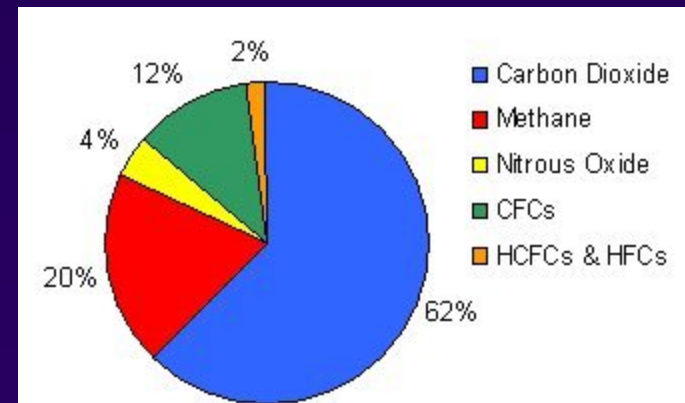
contribution of separate gases:

■ contribution of CO₂
▨ contribution of N₂O



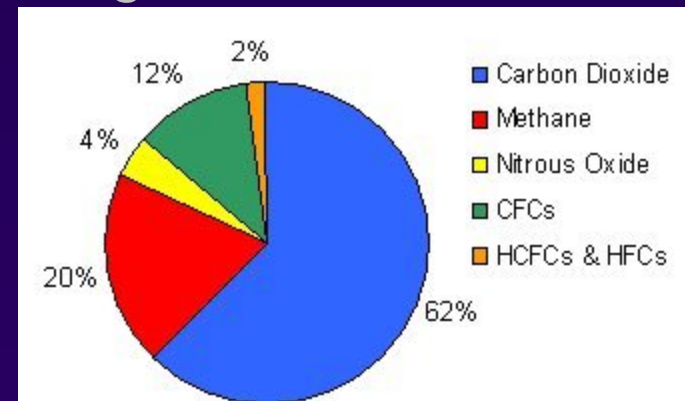
Introduction

- There's many GHGs
 - Water vapor
 - Human activity does not affect water vapor concentrations globally
 - Biogenic
 - CO_2 , N_2O , CH_4
 - Non-biogenic
 - Fluorinated gases used in fire extinguishers and refrigerators
 - SF_6 , HFC-23, Perfluorocarbon

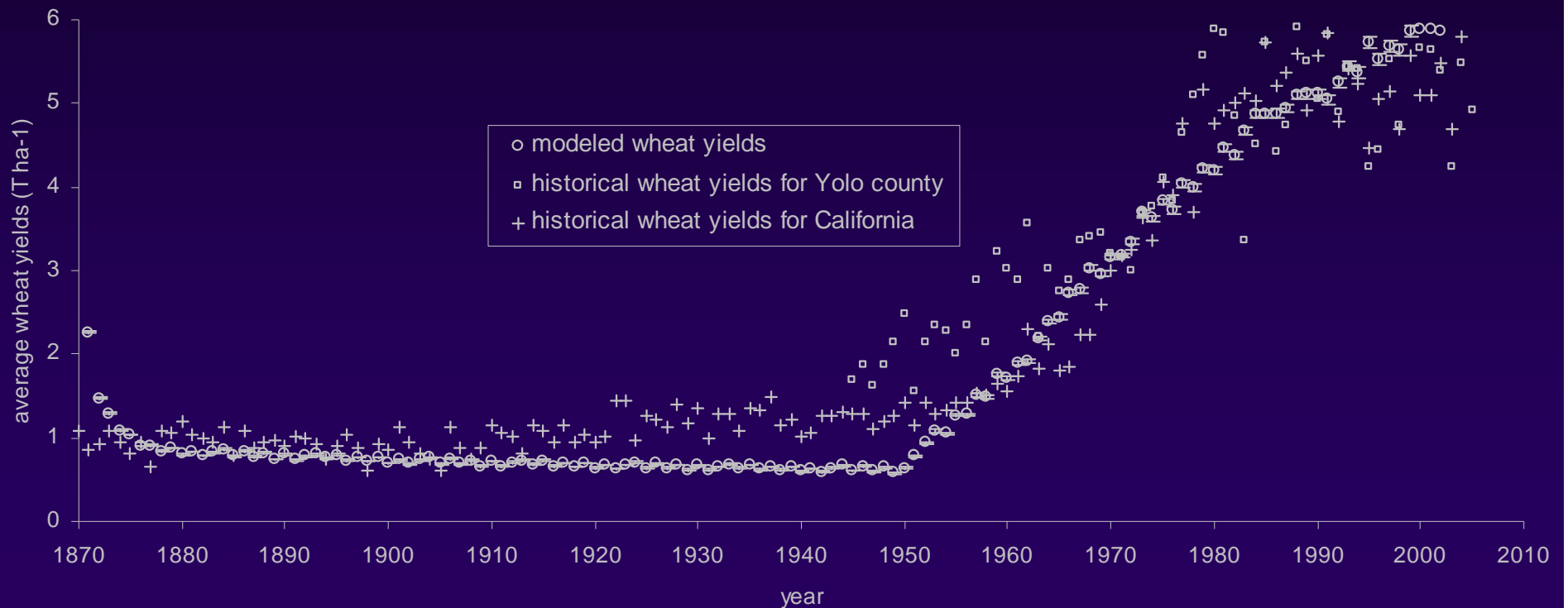


Introduction

- There's many GHGs
 - Water vapor
 - Human activity does not affect water vapor concentrations globally
 - Biogenic
 - CO_2 , N_2O , CH_4
 - Non-biogenic
 - Fluorinated gases used in fire extinguishers and refrigerators
 - SF_6 , HFC-23, Perfluorocarbon

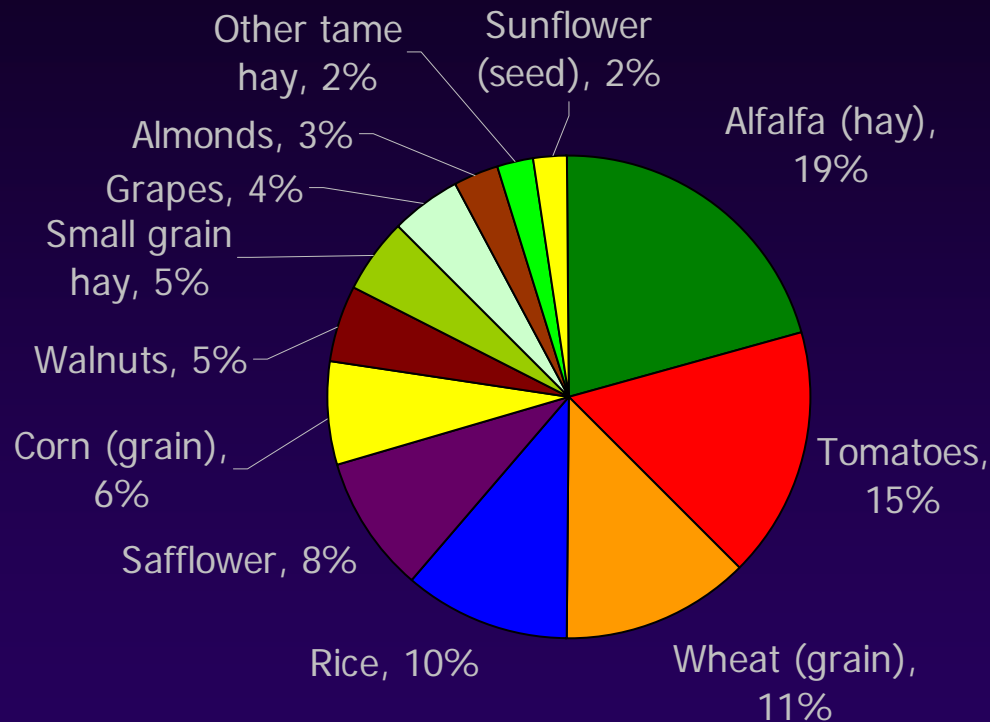


Validation: historical yields



Results: Yolo county

5 main crops
(no rice) in typical
rotations



USDA 2002 Census